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ABSTRACT

Under a grant funded under the Women's Educational Equity Act, the Department of Freshman Engineering at Purdue has developed a model program for freshmen women entering engineering. The program focuses on an experimental course that provides beginning engineering women and men with: (1) hands-on laboratory experiences; (2) discussions by various model lecturers of contemporary problems, including environment, energy, and productivity; and (3) career planning sessions, including the use of interest inventories. Pre-testing and post-testing with standardized instruments and special surveys were used for evaluation of experimental and control groups with generally positive results. (Author)

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A MODEL RESEARCH PROGRAM TO PROVIDE EQUITY FOR WOMEN ENTERING ENGINEERING[1,2]

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By

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Abstract

Under a grant funded under the Women's Educational Equity Act, the Department of Freshman Engineering at Purdue has developed a model program for freshman women entering engineering. The program focuses on an experimental course which provides beginning engineering women and men with (1) hands-on laboratory experiences; (2) discussions by various role model lecturers of contemporary problems, including environment, energy, and productivity; and (3) career planning sessions, including the use of interest inventories. Pre-testing and post-testing with standardized instruments and special surveys were used for evaluation of experimental and control groups with generally positive results.

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[1] A paper presented at the 1978 American Educational Research Association Annual Meeting in Toronto, Canada, March 1978.

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A MODEL RESEARCH PROGRAM TO PROVIDE EQUITY FOR WOMEN ENTERING ENGINEERING[1]

By

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NATURE AND PURPOSE

Women in the future will spend a major proportion of their lifetimes working, and the greatest growth in U.S. employment will be in professional occupations. Women have traditionally not entered many professional fields including engineering. Engineering is one of the largest professions in the U.S., employing over a million engineers in 1970 and is expected to reach one and a half million in the 1980's. However, engineering has been primarily a male profession with less than 1% female, one of the lowest in all professions and occupations and the lowest in the science fields. (National Science Foundation, 1975). Nonetheless, women are beginning to enroll in engineering colleges in unprecedented numbers and proportions, e.g., a sevenfold increase in seven years nationally (1181 in 1960 to 8545 in 1975) and even greater growth rates at many institutions, e.g., 1972-77, at Purdue University - a tenfold increase (27 to 284 freshman) in five years. There are similar encouraging signs at the demand level, which have been stimulated in part by affirmative action and equal employment opportunities. The College Placement Council (1975,76) and university placement centers also indicated that graduate engineering women are

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[1] Paper presented at the 1978 American Educational Research Association Annual Meeting in Toronto, Canada, March 1978.

as likely or more likely to seek and be granted job interviews and job offers and report slightly higher mean starting salaries.

Current studies and studies over the past several years have documented a variety of problems women entering engineering and other non-traditional programs are likely to encounter (Davis, 1977) including both lack of appropriate knowledge and indecision as to a specific area within their field of interest (Ott, 1977). Lack of appropriate knowledge of women in engineering was documented as early as 1962 by Dement. By talking with women entering mechanical engineering, she found that these women encountered difficulties because of the inadequacy of their vocabularies due to differences between their experiences and those of men. Shaycoft (1967), in the Project Talent Study of the growth of cognitive skills during the high school years, provides concrete evidence for this. High School men and women who were tested at both grades 9 and 12, showed substantial differences in several areas of knowledge, which are basic to the study of engineering, including physical science, aeronautics, electronics, and mechanics. Furthermore, studies conducted by Erlick and LeBold, (1975) and LeBold, Bond, and Richard (1975), indicate that men are much more likely than women to have hobbies, interests and educational experiences which are engineering related and provide technical "hands-on" experiences. It was also found that students who had these experiences, were much more likely to enter scientific fields. Additionally, women who decide to enter engineering, do so at a much later time in high school and are much more likely to be undecided on a field of specialization.

Based on these findings and related programs designed for women in non-traditional scientific fields at the University of Oklahoma (Pollack and Little, 1973 and Shay, 1975);Cornell (Hall and Hall, 1975); and Purdue (Brown, 1975); the Purdue University Department of Freshman Engineering designed, field tested, and evaluated a model program for freshman women in engineering. The project was funded by a grant from the U.S. Office of Education under the Women's Educational Equity Act (WEEA).

Purdue's WEEA Women in Engineering Program focused on the development of an experimental course directed at meeting the special needs of freshman engineering women. The needs included "hands-on" experiences, role-models, understanding the relationship between engineering and societal problems and career counselling. The program includes the use of "hands-on" laboratory sessions relevant to engineering, role-model lecture-discussions dealing with problems related to engineering, and group and individual career counselling sessions.

OBJECTIVES

The primary objectives of the course are:

(1) To provide laboratory experiences for freshman engineering students, particularly women which include knowledge and "hands-on" skills related to engineering.

(2) To provide a variety of role-model lecturers for freshman engineering students to help them identify career opportunities and interests in various fields of engineering and to help them develop an understanding of societal engineering problems.

(3) To provide career counseling for freshman engineering students to help them identify their abilities and interests and to integrate this information with their understanding of fields of engineering into a meaningful career plan.

(4) To compare and evaluate the experiences of men and women who participated in the experimental program with similar men and women who did not participate in the program.

METHOD

Subjects: 2000 freshman engineering students were given information about the experimental course during the fall semester of 1976. Subjects were selected randomly from 250 freshman engineering students of the 2000 (75 women and 175 men) who expressed an interest in the course. The assignment of students in the course included two experimental sections, one containing primarily women (22 women and 4 men actually enrolled) and one containing about half women and half men (15 women and 11 men actually enrolled). Two control groups were used for the study. One control group consisted of persons who had signed up for the course but were assigned to the control group (15 subjects, 10 women and 5 men participated). The other control group consisted of students enrolled in a freshman engineering design course (61 men and 4 women participated).

Procedure: The experimental course, Engineering 195, was offered during the spring semester of 1976. The course consisted of a two hour laboratory and a one hour lecture each week. During the laboratory sessions, students worked with hand tools, power tools, electricity, metals, plumbing, small engines, automotives, and turbine engines.

The laboratory experiences were aimed at helping students develop technical skills as well as a knowledge related to engineering.

During the lecture sessions a variety of male and female role models from the university, industry, and government discussed current problems with which engineers deal including problems of energy, the environment, transportation, productivity, and bio-medicine.

Three career counseling sessions were held during the semester as well. The interaction of interests, abilities, goals and aspirations in relation to career choice was discussed; the Purdue Engineering Interest Questionnaire (LeBold, 1976) and the Strong Campbell Interest Inventory (Strong-Campbell, 1974) were interpreted; and during the final session, students wrote their biographical introduction for a banquet in the year 1996 at which they were to be the principal speakers.

During the semester the students kept journals in which they wrote their impressions of the lectures, laboratories, and career counselling. The purpose of the journals was to help students become more aware of their career interests, but the journals were also a valuable tool for the evaluation of the course.

Evaluation: Six standardized tests were used to evaluate the effectiveness of the laboratory experience in increasing knowledge in technical areas. These tests include the Tool Knowledge Test, the Mechanical Information Test, the Electrical Information Test (Educational Testing Service, 1962), the Auto Mechanics Test (Campbell and Johnson, 1969), the Bennett Mechanical Comprehension Test (Bennett, 1968), and the Purdue Mechanical Adaptability Test (Lawshe and Tiffin, 1946).

Table 1 presents the number of items,and Kuder-Richardson 20 reliability coefficients for each cognitive test.

To evaluate changes in goals, interests, attitudes, perceived capabilities, and experiences, a survey of 150 items was developed specifically for the program.

All of the pre-testing including the use of the standardized tests and the survey was completed during the first week of classes. Post-testing with the same instruments was completed during the last week of classes.

Analysis of Data: The six pre-tests and post-tests scores for the various groups were analyzed separately using analysis of variance and analysis of covariance in which the pre-test was the covariate and the post-test was the variate. Sex differences were also examined. The pre and post-tests were analyzed by using one-tailed t-tests of differences between correlated means to determine the significance of gains for each individual group (experimental women, experimental men, control women, control men, combined experimental, and combined control groups); t-tests of difference in the gain scores were also used to compare experimental and control women, experimental and control men, experimental women and control men and combined experimental and control groups. The total score based on the sum of the six tests was also analyzed in the same manner as the individual sub-tests.

Items on the pre-survey and post-survey were analyzed by a chi-square statistic in which four groups were used: experimental men, experimental women, control men and control women. The items were

TABLE 1

Cognitive Test Names, Abbreviations, Number of Items and Reliabilities of Scales Used in 1977 Engineering 195A and B Experimental Model Course on Engineering Skills and Career Planning

TEST	ABBR.	# of ITEMS	K-R20 RELIAB.
Purdue Mechanical Adaptability Test	PMA	60	.91
Bennett Mechanical Comprehension Test	BMC	68	.93
Tool Knowledge Test	TKT	30	.80
Mechanical Information Test	MIT	30	.90
Electrical Infromation Test	EIT	30	.93
Auto Mechanics Test	AMT	20	.93
Mechanics Test	MCT	30	.94
Total (Sum of all Tests except mechanics)	SUM	188	.96 (est.)

also factor analyzed and made into 20 separate Likert type scales. Three of the scales, The Women in Engineering Scales, were adapted from the Women as Managers Scale (Peters, Terborg, Taynor, and Ilgen, 1974). Reliability co-efficients were obtained for the scales using the pre-survey. The pre-scales and post-scales were then separately analyzed by group and sex, as well as differences between experimental men, experimental women, control men and control women. Table 2 presents the abbreviations, number of items and Cronbach's Alpha reliability coefficients for each scale.

RESULTS

Cognitive Data: As may be noted in Table 3 the combined experimental and male groups had significantly higher adjusted mean scores than control groups on the Purdue Mechanical Adaptability Test, the Mechanical Information Test and the total score based on the analysis of covariance using the pre-test as a covariate. Except for the Mechanical Information Test there were no statistically significant differences between the adjusted means scores of the experimental and control women. Table 4 summarizes the results of testing the significance of the gain scores. Highly significant gains for women in the experimental group were observed on all tests except the Auto Mechanics Test ($p < .001$) with significant and similar results for the combined experimental group ($p < .001$). The experimental men also showed significant improvement on all,but the Bennett Mechanical Comprehension. The control groups (men, women, and combined) also showed slight gains on most of the cognitive tests. The differences in gain scores using t-tests in Table 5 indicate significantly greater gains on all but one test (the Auto Mechanics

TABLE 2

1977 AFFECTIVE SURVEY SCALES USED IN PRE AND POST TESTING OF PURDUE FRESHMAN IN WOMEN'S EDUCATION EQUITY ACT MODEL PROGRAM EVALUATION

NAME OF SCALE	SCALE ABBR.	# OF ITEMS	PRE TEST ALPHA RELIAB. COEF.
Importance of Hands-on-Skills	HOSI	4	.84
Importance of Knowing About Engineering Prob.	EPKI	9	.73
Importance of Career Plans and Self Identity	CPII	4	.61
Achievement of Hands-on Skills	HOSA	4	.87
Achievement of Knowledge About Engr. Problems	EPKA	9	.78
Achievement of Career Plans and Self Identity	CPIA	4	.69
Sensory Skill Capabilities	SSK	8	.80
Psycho-Motor Skill Capabilities	PMSK	16	.93
Capability of Adjusting Mechanical Equipment	MEA	10	.84
Observational Skill Capabilities	OBSK	10	.80
Personal and Social Development	PSD	4	.75
Engineering Preferences	ENGP	8	.78
Participation in Engineering & Science Disc.	ESC	12	.84
Participation in Technical Activities	TTA	9	.92
Participation in Engr. & Science Activities	ESA	8	.76
Participation in Engr. & Science Programs	ESP	5	.88
*Competitive Ability of Women in Engineering	WIEC	12	.94
*Femininity of Women in Engineering	WIEF	5	.85
*Leadership Ability of Women in Engineering	WIEL	4	.82
Career Planning Goals	CPG	3	.76

* Adapted from the Women as Managers Scale by Peters, Terborg, Taynor and Ilgen.

TABLE 3

Analysis of Covariance Significance Levels and Raw Score Adjusted Means for the Tests of Technical Knowledge.

	ADJUSTED MEANS					
	WOMEN		MEN		COMBINED	
	EXPER.	CONTROL	EXPER.	CONTROL	EXPER.	CONTROL
MECHANICAL ADAPTABILITY	32	30	35	31 [2]	33	30 [2]
MECHANICAL COMPREHENSION	55	55	54	53	54	54
TOOL KNOWLEDGE TEST	21	20	23	21	21	21
MECHANICAL INFORMATION	21	18 [3]	23	20 [2]	22	19 [3]
ELECTRICAL INFORMATION	21	19	22	21	21	20
AUTO MECHANICS TEST	5	5	6	5	5	5
TOTAL	156	149	166	149 [3]	157	149 [3]

[1] $p < .05$
[2] $p < .01$
[3] $p < .001$

TABLE 4

Raw Score Means and t-Test Significance Levels for Differences Between Correlated Pre and Post Cognitive Test Means for Each Group in the Purdue 1977 WEEA Engineering Skills and Career Planning Study.

	GROUPS											
	EXPER. WOMEN		CONTROL WOMEN		EXPER MEN		CONTROL MEN		TOTAL EXPER		TOTAL CONTROL	
COGNITIVE TEST *	PRE	POST	PRE	POST	PRE	POST	PRE	POST	PRE	POST	PRE	POST
PMA	22	27 [3]	21	24	34	39 [3]	32	34 [1]	25	31 [3]	30	32 [2]
BMC	48	51 [3]	49	52	59	59	55	55	51	53 [3]	54	55 [1]
TKT	16	18 [3]	15	17 [1]	25	26 [1]	22	23	18	20 [3]	21	21 [1]
MIT	15	19 [3]	14	14	21	24 [3]	21	22 [1]	16	20 [3]	19	20 [1]
EIT	16	19 [3]	15	17	21	23 [2]	21	22 [1]	17	20 [3]	20	21 [2]
AMT	4	4	3	4 [2]	5	7 [1]	6	6 [1]	4	5 [1]	5	6 [1]
*SUM	120	137 [3]	116	128 [2]	163	178 [3]	156	161 [3]	136	152 [3]	150	157 [3]
No. of Cases	(37)	(37)	(14)	(14)	(14)	(14)	(61)	(61)	(51)	(51)	(75)	(75)

* Cognitive test titles:

PMA - Purdue Mechanical Adaptability Test
BMC - Bennett Mechanical Comprehension Test
TKT - Tool Knowledge Test
MIT - Mechanical Information Test
EIT - Electrical Information Test
AMT - Auto Mechanics Test
*SUM - Total of all (Due to rounding error totals may not be equal)

Signifiance levels based on 1 tailed t-tests:

[1] $p < .05$
[2] $p < .01$
[3] $p < .001$

TABLE 5

Raw Score Differences Between Cognitive Pre and Post-Test Means, Differences Between Differences of Experimental and Control Groups, and t-Test Significance Levels for the Differences Between Differences for the Groups

GROUPS

COGNITIVE TESTS	WOMEN EXPERIM $\bar{X}_2-\bar{X}_1=DE$	WOMEN CONTROL $\bar{X}_2-\bar{X}_1=DC$	WOMEN DE-DC	WOMEN p	MEN EXPERIM $\bar{X}_2-\bar{X}_1=DE$	MEN CONTROL $\bar{X}_2-\bar{X}_1=DC$	MEN DE-DC	MEN p
PMA	5.7	3.7	2		5.6	1.6	4	2
BMC	2.8	2.4	.4		.29	.61	-.32	
TKT	2.1	1.8	.3		.93	.46	-.47	
MIT	3.9	.9	3.0	2	3.57	.85	2.72	2
EIT	2.6	1.7	.9		2.29	.72	1.57	1
AMT	.65	1.14	-.49		1.79	.59	1.20	
SUM	17.8	11.6	6.2	1	14.4	4.8	9.6	3
N. of Cases	(37)	(14)			(14)	(61)		

COGNITIVE TESTS	TOTAL EXPERIM $\bar{X}_2-\bar{X}_1=DE$	TOTAL CONTROL $\bar{X}_2-\bar{X}_1=DC$	TOTAL DE-DC	TOTAL p	EXPERIM WOMEN CONTROL MEN $\bar{X}_2-\bar{X}_1=DC$	EXPERIM WOMEN CONTROL MEN DE-DC	EXPERIM WOMEN CONTROL MEN p
PMA	5.7	2.0	3.7	3	1.6	4.1	3
BMC	2.12	.94	1.18	1	.61	2.20	3
TKT	1.78	.71	1.07	1	.46	1.65	2
MIT	3.80	.85	2.95	3	.85	3.04	3
EIT	2.53	.91	1.62	2	.72	1.90	3
AMT	.96	.69	.27		.59	.06	
SUM	16.9	6.1	10.8	3	4.8	13.0	3
N. of Cases	(51)	(75)					

Based on a chi-square analysis of frequencies:

[1] $p < .05$
[2] $p < .01$
[3] $p < .001$

Test) for the combined experimental over the control group and for the experimental women over control men. The experimental women had significantly greater gains than the control women on the Mechanical Information Test ($p < .01$) and on the total score ($p < .05$). Significantly greater gains were also found for experimental over the control men on the total and three cognitive measures.

The analysis of variance of the pre and post tests both revealed significant differences according to sex on all tests ($p < .001$), although significant improvement was found for both men and women in the experimental groups (on the previously mentioned tests) when they were analyzed separately by the analysis of covariance and t-tests. Figure 1 contains a summary profile showing pre and post test results for experimental women and control men. Although the women were not able to completely "catch up" with the men in technical knowledge, there was a substantial gain.

The chi-square analysis of the pre-survey items revealed that women generally felt they had less technical capability than men. The post-survey, however, revealed that women in the experimental group had increased confidence in their technical skills and that they felt they had gained a great deal in their technical knowledge. The analysis of variance of the pre-survey and post-survey scales also showed that the experimental women gained in their confidence in performance of technical skills and in their preceived achievement of technical knowledge. Changes in goals, interests, and attitudes toward women in engineering for all groups were minimal although women tended to have stronger and more positive attitudes in both the pre-surveys and post-surveys. Table 6 contains mean scores on the pre and post survey for the various scales used to measure the affective impact of the program.

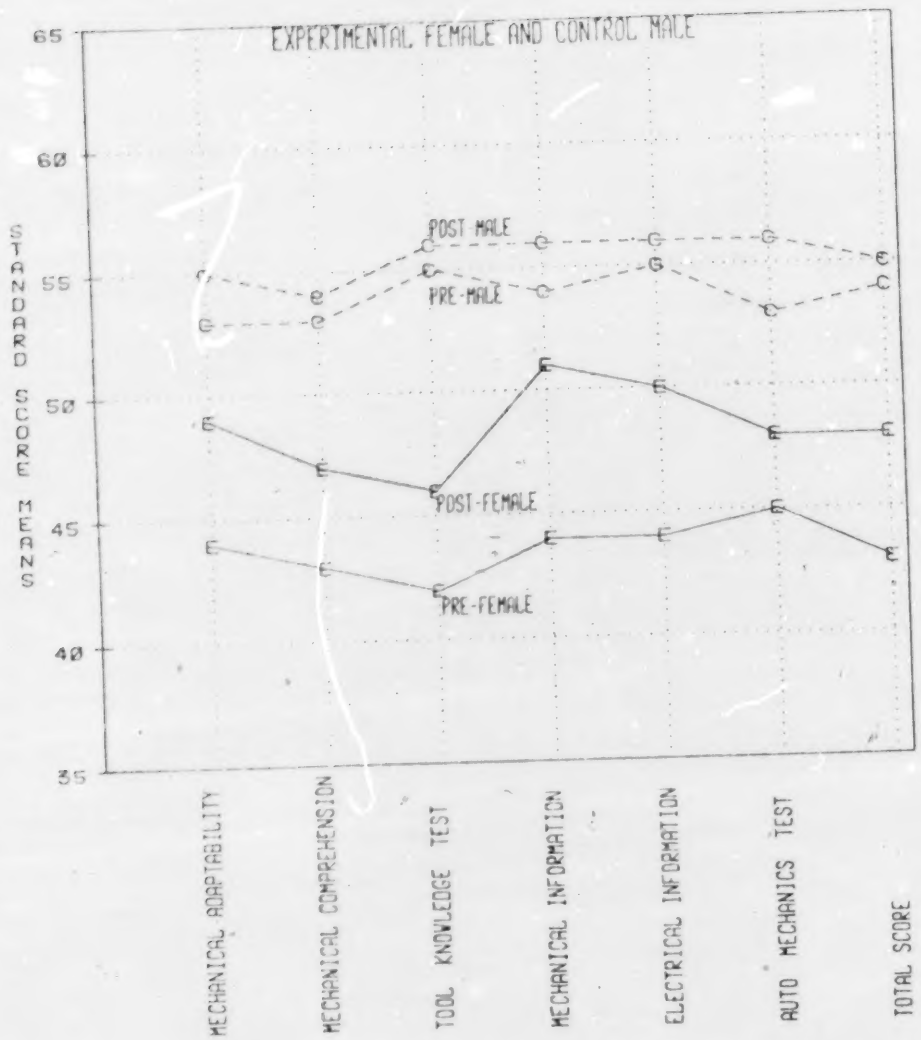

Figure 1. The profile shows the performance of experimental women compared to control men on each of the pre- and post-cognitive tests.

TABLE 6

Raw Score Means and T-Test 2 Tailed Significance Levels for Differences Between Correlated Pre and Post Survey Scale Means for Each Group in the Purdue 1977 WEEA Engineering Skills and Career Planning Study.

	EXPER. WOMEN		CONTROL WOMEN		EXPER. MEN		CONTROL MEN		TOTAL EXPER.		TOTAL CONTROL	
SURVEY SCALES	PRE	POST	PRE	POST	PRE	POST	PRE	POST	PRE	POST	PRE	POST
Educational Goals - Importance												
Hands-on Skills	13	13	11	11	13	12	11	11	13	13	11	11
Knowing About Engineering Problems	31	31	30	29	30	29	29	28 [2]	31	30	29	28 [3]
Career Plans & Self Identity	15+	15-[1]	15	15	15	14 [1]	15	13	15	14 [2]	15	14 [3]
Educational Goals - Achievement												
Hands-on Skills	13	12	6	7	12	11	8	9	13	12	8	8
Knowledge About Engineering Problems	26	28	20	22	27	25	23	23	26	27	23	23
Career Plans & Self Identity	12	12	11	11	14	12 [1]	12	11	13	12 [1]	12	11 [2]
Capabilities												
Sensory Skills	27	29 [1]	29	28	29	30	28	28	28	29	30	28 [2]
Psycho-Motor Skills	56	59 [1]	57	54	62	61	61	53	57	60	60	57 [2]
Mechanical Equipment Adjusting	34	37 [3]	34	35	39	38	36	35	35	37 [1]	35	35
Observational Skills	32	34 [2]	32	32	36	37	35	34	32	35	34	34
Personal & Social Development	12	14 [2]	12	13	12	12	11	12 [3]	12	13 [1]	11	12 [3]
Preferences												
Engineering	23	24	23	24	27	26	24	24	24	25	24	24
Activities												
Engineering & Science Discussion	37	45 [3]	38	40	37	44 [1]	37	38	37	45	37	38
Tools and Technology	19	35 [3]	18	20	26	32 [1]	24	24	21	34 [3]	23	23
Engineering & Science	18	21 [2]	18	20	22	23	18	21 [3]	19	21 [1]	18	21 [3]
Engineering & Science Programs	8	11 [3]	9	9	10	13	9	11 [3]	9	12 [3]	9	11 [3]
Women in Engineering Attitudes												
Competitiveness	55	54	58	53	47	46	46	41 [2]	53	52	49	44 [3]
Femininity	21	20	21	20	16	15	15	15	19	19	16	16
Leadership	18	17	19	17 [1]	14	14	14	13 [2]	17	16	15	14 [3]
Career Planning	13	14	14	13	13	13	13	12 [2]	13	13	13	12 [3]
Total Scores												
Importance of Goals	59	59	57	55	58	55	55	52 [1]	59	58	55	52 [3]
Achievement of Goals	51	52	38	40	53	50	44	43	51	51	42	42
Technical Capability	148	159 [3]	151	150	168	164	161	154 [1]	154	161	159	154 [1]
Engineering-Technical Activities	82	112 [3]	82	89	95	111	88	94 [3]	86	112 [3]	87	93 [3]
Women in Engineering Attitudes	94	92	98	90	78	75	76	70 [2]	89	87	80	74 [3]
No. of Cases	(35)	(35)	(15)	(15)	(13)	(13)	(63)	(63)	(48)	(48)	(78)	(78)

Based on a chi-square analysis of frequencies:

[1] $p < .05$
[2] $p < .01$
[3] $p < .001$

Lastly the verbatim comments made by the students in their journals and in the post-survey give insight into the affectiveness of the program. Selected comments are as follows:

Role Model Lecture-Discussions: "Two environmental engineers talked to us about their jobs. Both were very interesting. I think that environmental engineering might be what I want to do as their jobs sounded fascinating, and I am concerned about the environment." (Female Journal)

"Definitely provided the overall picture of engineering relationships." (Female Final Survey)

Hands-On Laboratory: "Can an extension cord I make be trusted? You all seem to think so. I know it was fun. Sometimes I can't believe the things we do in these labs. My father will be amazed at me. I won't mind helping him fix things anymore because I've soldered and drilled and stripped wires too, and now I really know I can do it. It's a lot less of an obstacle now. Each lab helps me to try new things I've always avoided." (Female Journal)

"It reminded me of my 8th and 9th grade shop classes, though it was better than taking a test. I do enjoy working with my hands and seeing the finished product." (Male Journal)

Career Planning: "This is really making me think! I never considered career planning a process before. Worse, I don't like to think about goals changing as our interests change." (Female Journal)

"The career planning, particularly the review of the Strong-Campbell Interest Survey results, was helpful." (Female Final Survey)

DISCUSSION

The pilot field test and the model program designed for women entering engineering indicate that a single course can provide women with those experiences they often lack and which tend to put them at a disadvantage in engineering education. The "hands-on" laboratory resulted in substantial, although not complete, gains in technical knowledge for women in the experimental group compared to men in the control group. Student journals showed evidence that a great deal of thought was going into the formulation of specific career plans, after each role-model lecture-discussion session and career counselling session. Evidence from the survey scales indicates increased self-confidence of women in their technical knowledge and laboratory skills, as well. Final course evaluations by the students indicated that they were generally pleased with the course.

Based on student and staff observations and evaluations revisions were made in the pilot course. The course was changed primarily to more nearly meet the individual needs of the students. It was divided into modules including the "hands-on" lab, the role-model lecture-seminar, and a recitation-discussion which includes engineering problems and career counselling. Students can select a single or combination of modules that meet their individual needs. The career counselling-discussion module was reserved primarily for those people who were undecided. Students who were interested in the course filled out a form rating their knowledge of engineering problems, technical knowledge, and choice of school. Students were given priority on the basis of their ratings, so that students with the greatest need would have the first chance to

sign up for the course. Space was reserved for twice as many students (120 vs. 60) as the previous year, but only about half of those who indicated an interest (150 of 300) could be accommodated.

The revised course is presently being offered and field tested. The staff anticipates even greater success with the modular approach. Present plans indicate the University will continue to offer the "hands-on" laboratory both semesters during the academic year and the seminar and career counselling modules during the second semester of the academic year.

The results of the first years experiences were shared with other colleagues concerned with womens programs in engineering and higher education at an invitational workshop held at Purdue, December 1-2, 1977. Press releases, the annual report and technical papers presented at local, regional, national (Butler,et al. 1977 A,B; LeBold,et al.1977), and international meetings (LeBold, Butler and Knigga, 1978) have also been used to disseminate information regarding the model program. It is anticipated that other institutions and non-traditional fields will adopt similar, but probably not identical programs depending on their individual needs and resources.

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